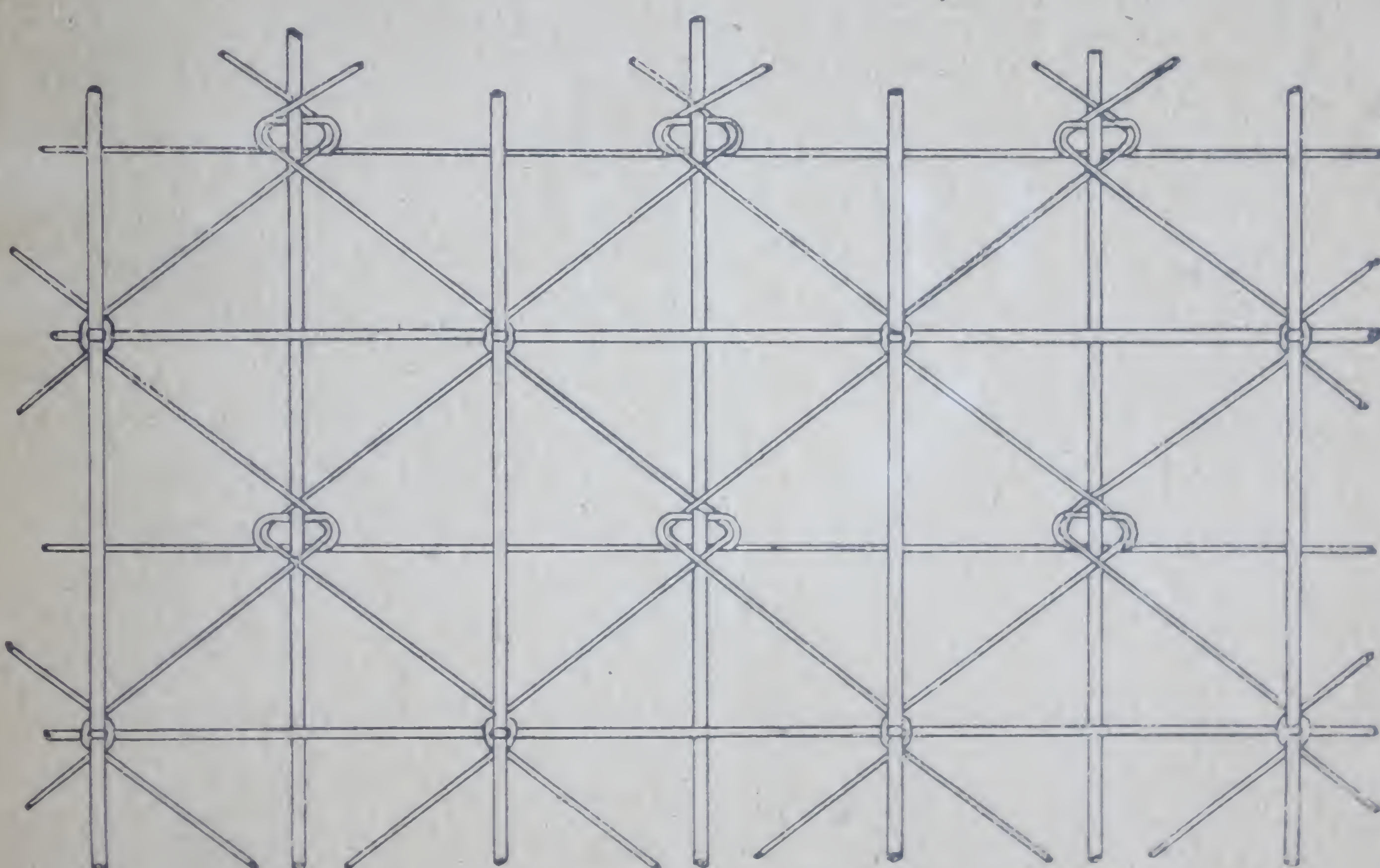
PATENT PYRAMIDAL
Interlocked Reinforcement



PLAN.

Patentees and Manufacturers:

THE WALKER-WESTON CO., LTD.,
EMPIRE HOUSE,
7, WORMWOOD STREET, LONDON, E.C. 2.

Telegraphic Address: PYRAMINWAL, AVE, LONDON.
Telephone No.: LONDON WALL 7150.
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Codes
- "A.B.C." 5th Edition.
- "Western Union"
- "Liebers."
- "Engineering 2nd Edition."

PATENT PYRAMIDAL
Interlocked Reinforcement

Suitable for Reinforcement of Roads, Rafts, Retaining Walls, Reservoirs, Silos, Coast Works, and other structures.

Particularly adaptable for the rapid and economical construction of Houses on the hollow-wall principle.

The Port of London Authority use the system extensively in connection with their vast schemes of improvement.

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EMPIRE HOUSE,
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Telegraphic Address: PYRAMINWAL, AVE, LONDON.
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Cable Address: WALKWESTCO, LONDON.

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"A.B.C." 5th Edition.
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PYRAMIDAL INTE

SUITABL

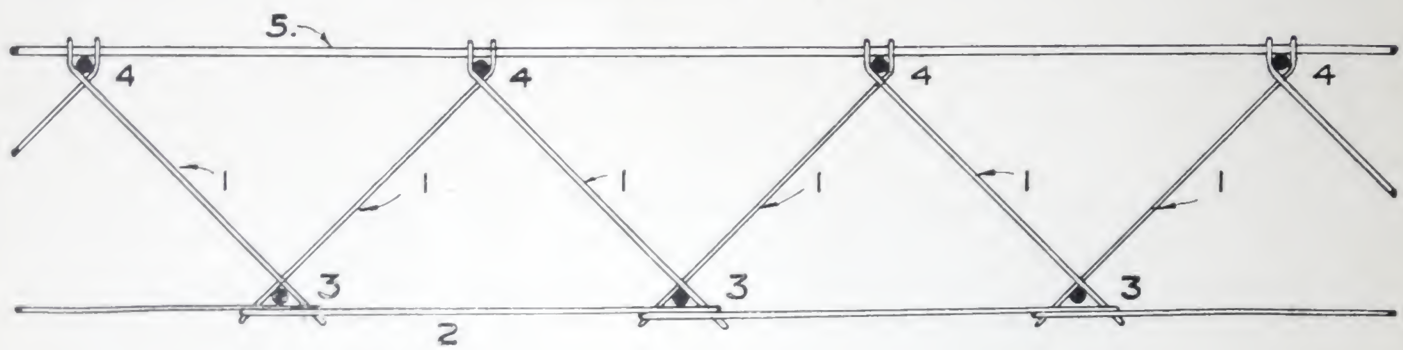
Roads, Rafts, Floors, Reservoirs, Retainin

Coast Defence Works

PATENT No

Fig. A

SECTION A.B.



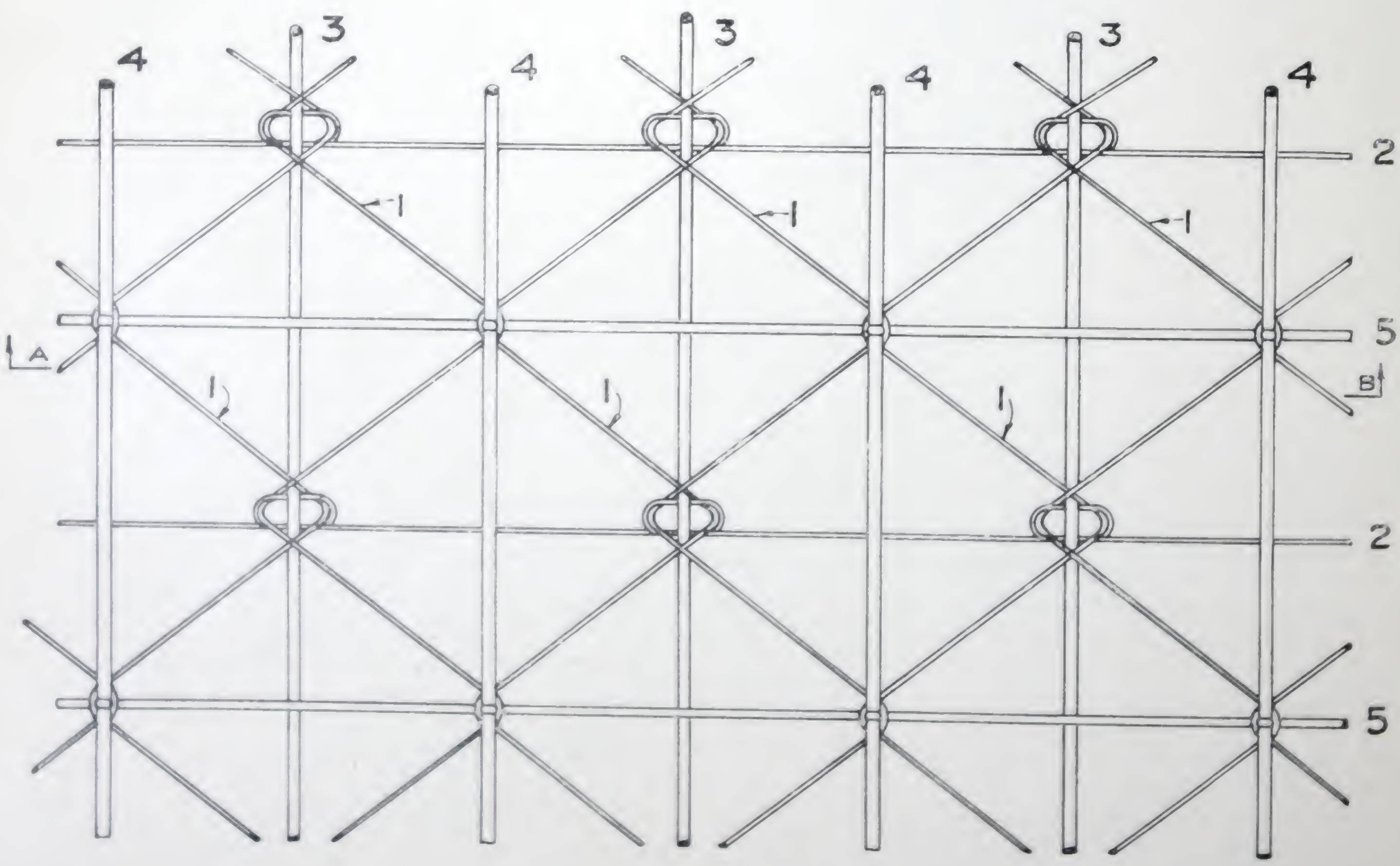


Fig. B

PLAN.

OCKED REINFORCEMENT

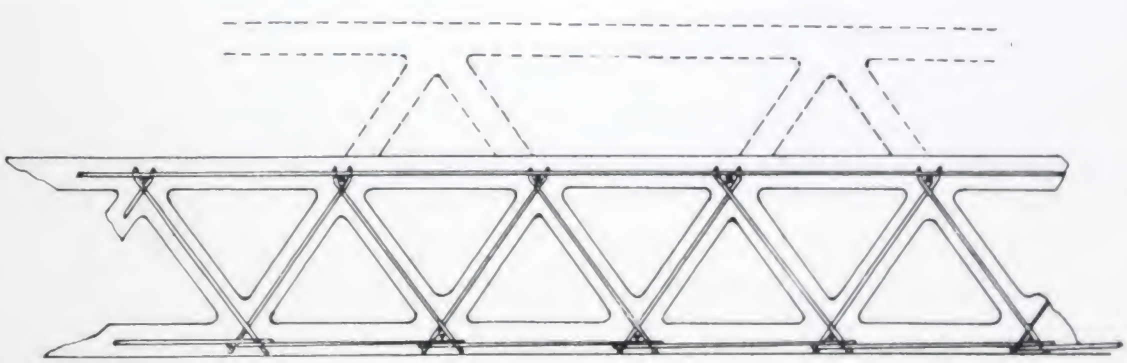
R

alls, Silos, Hoppers, Sides of Buildings,
wage Works, Ships, etc.

7915. 8/6/17.

Fig. C

ELEVATION OF ZIG-ZAG BARS (1).



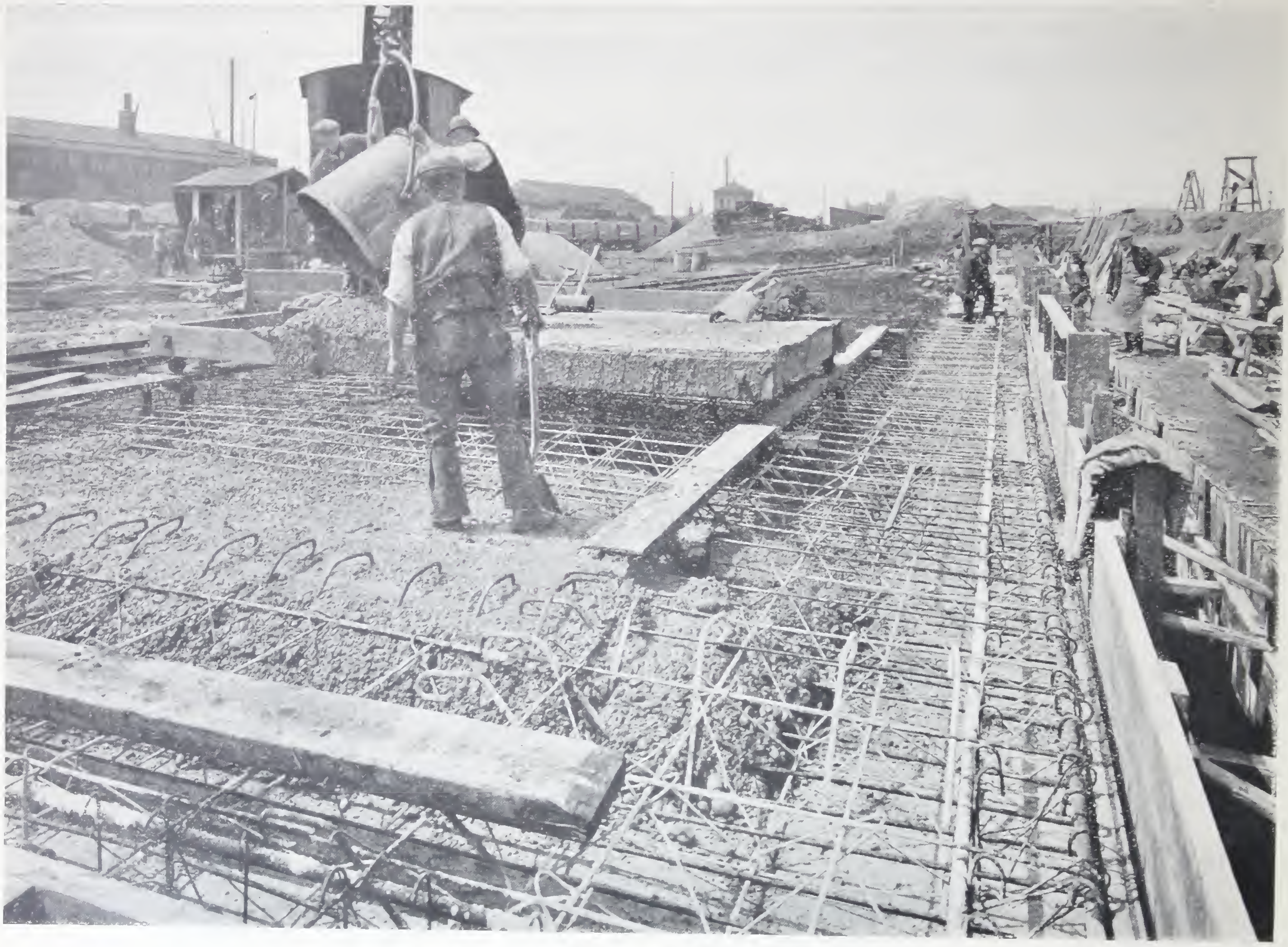
SECTION.

Fig. D

Shewing Hollow Concrete Wall strengthened with Pyramidal Interlocked Reinforcement, suitable for Buildings, Retaining Walls, Ships, Barges, etc.

The thickness of the wall can be increased as shewn by the dotted lines without increasing the weight per square foot of the wall surface.

The strength of the wall as a beam is thereby proportionately increased due to the greater moment of inertia of the section, assuming the weight of reinforcing steel in the outside slabs are the same in both cases.



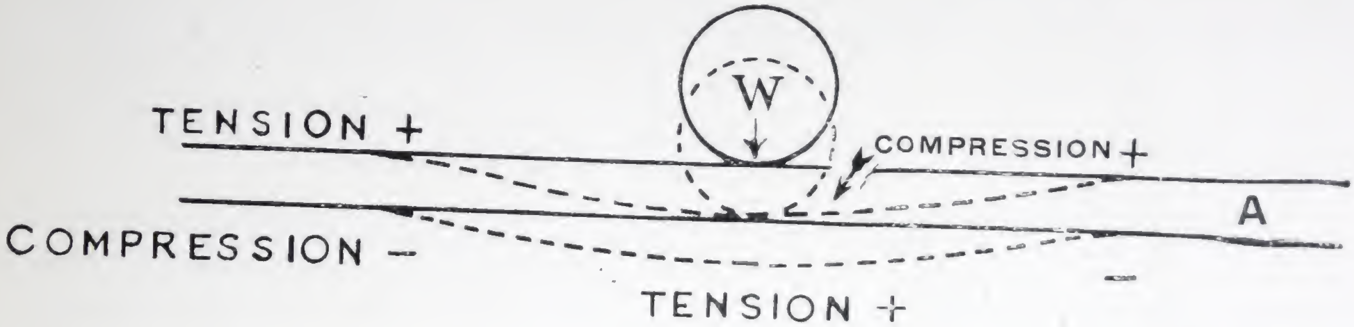
THE AVERAGE ENGINEER on his introduction to reinforced concrete, is apt at first sight to consider its method of construction very simple. He is aware that concrete is a material very strong in compression but weak in tension, and that consequently steel bars are embedded in the concrete to make up for the deficiency in tensile strength. As he goes deeper into the subject he finds not only is concrete weak in tension, but it is also very weak in shear or diagonal tension, and it has to be further reinforced to meet these stresses. After he has mastered the theory of designing a suitably reinforced structure, the next problem he has to contend with is the carrying out of the work in such a manner that when the same is completed **the reinforcement shall in all cases be in its correct position** in relation to the surrounding concrete.

This latter operation would, to an engineer used to structural steelwork erection, at first sight appear to offer no great difficulty. If he has persevered and arrived at this stage he may, in his first efforts, be easily disillusioned on this very vital point, and find that due either to bad design, or bad workmanship on the part of the steelworkers or the concreting gang, the reinforcement is not in the position intended. The tendency has been therefore for the average engineer to relegate, perhaps wisely, the responsibility of the design of reinforced concrete structures and to advise his clients or employers to call in the services of reinforced concrete specialists and so transfer to the latter the onus of the economical and safe design and construction of the structure.

The bulk of reinforced concrete work, however, consists of simple classes of structures now well within the compass of an engineer provided with ordinary labour and the necessary plant and labour-saving devices. Such structures include reinforced concrete in roads, raft foundations, retaining walls, buildings, reservoirs, pontoons, silos and such-like.

AN EXAMPLE OF A REINFORCED CONCRETE ROAD.

Let us take as an example what one would naturally consider to be the simplest form of a reinforced concrete structure, viz. :—a reinforced concrete road or similar raft foundation laid on an earth formation having a very small load carrying capacity per super foot of area. In this case little or no timber shuttering is required, and it is only necessary to place the steelwork in position and surround it with concrete. This sounds absurdly simple and really is so when the job is tackled correctly. (Strange though it may seem the problem has only been scientifically, economically and practically solved during the past two years). We will assume it is required to put down a reinforced concrete road, strong enough to carry a heavy rolling load over a bad formation.



We will call the load " W " and the raft " A." The raft tends to sag downwards immediately under the load with the underside of the raft in tension and the upper side in compression. A short distance away the raft is subject to contra-flexure, with the upper side in tension, and the lower side in compression. As the load is a rolling one, the various parts of the raft become subject to alternations of tension and compression at the top and bottom. Consequently the raft, in the circumstances, has to be reinforced with upper and lower layers of steel, but the concrete is subjected to varying stresses of shear or diagonal tension, and steel reinforcement must be provided to meet these stresses, consequently the upper and lower layers must be CONNECTED together by means of diagonal reinforcement.

PROVISION AGAINST CONTRACTION CRACKS.

In addition to the stresses imposed by the rolling load, provision must also be made against contraction cracks in the concrete due to the stresses set up by the concrete setting or by variations of atmospheric conditions. The daily variation of temperature in the surface of a concrete slab may be as much as 50°F. whereas the corresponding variation in the underside of the slab may not exceed 2°F. This being so, a layer of reinforcement near the underside of the slab is practically useless in preventing contraction cracks due to change of temperature. It should be obvious that for this purpose the reinforcement should be near the surface. These remarks apply with greater force when one considers the expansion and contraction stresses operating in the upper surface of the slab, respectively due to alternating states of moisture and dryness.

It is perhaps at this point just as well to lay stress upon the desirability of employing steel bars of as small section as possible on account of the important part played in reinforced concrete construction of the surface adhesion of the concrete to the reinforcing steel. As the area of a round bar is a function of the square of its diameter, and its circumference is directly proportionate to its diameter, it is obvious that the smaller the bars for a given amount of reinforcement the greater is the total amount of surface adhesion of the concrete to the steel. Anyone who has tried to place even a few long steel bars of small area and great flexibility in a single layer in a mass of concrete, and then after the concrete has been dumped over the bars and punned into place, has been prepared to say for a certainty that the bars were exactly in the positions he intended in the finished work, will at once concede that the successful solution of a top and bottom layer, connected together by means of diagonal tension members in such a mass of concrete, is a problem of great interest.

METHODS OF THE PAST.

Before explaining how it is easily accomplished, it may perhaps be as well to state that many thousands of square yards of concrete roads have been laid these past few years in situations, where, due to the good quality of the foundations, it was immaterial—save for setting and temperature stresses—whether the concrete was reinforced or not. The methods generally adopted have been :—

(a) To ignore the necessity for provision against stresses due to contraflexure, to contraction or expansion and to diagonal tension, and to merely embody in the raft a bottom layer of reinforcement consisting either of bars or expanded metal, or of wire meshwork.

(b) For want of a cheap and satisfactory method of providing for the diagonal tension stresses to accordingly ignore them, and to insert only a top and bottom layer of reinforcement.

A SAVING IN THE TOTAL COST OF REINFORCEMENT.

Provided the formation be rock, or an old consolidated road surface or other good foundation, either of the above methods in combination with costly and otherwise objectionable expansion joints may be partly successful, but had the problem been squarely faced in the first instance and solved in the manner shortly to be described, the provision of the steel reinforcement for diagonal tension stresses in conjunction with the same amount of metal in the top and bottom layers as in case (b) would have resulted in many instances in a great saving in the total cost of reinforcement, combined with greater efficiency.

This statement, astonishing as it seems, is literally true, and is due to the fact that by the method proposed the bars are delivered straight from the mills to the site of the work, and some of them cheaply and quickly bent and locked together to make a framework to which all additional bars required are easily and firmly attached.

In the case of proprietary reinforcements such as mesh-works of wire or bars electrically welded or woven together, many costs are incurred in charges for various railway journeys, manufacture, storage, advertisement, royalty charges, and profit before the material arrives at the site in sheets or rolls ready for laying in position in the work, hence such material works out at an exorbitant cost per unit of weight.

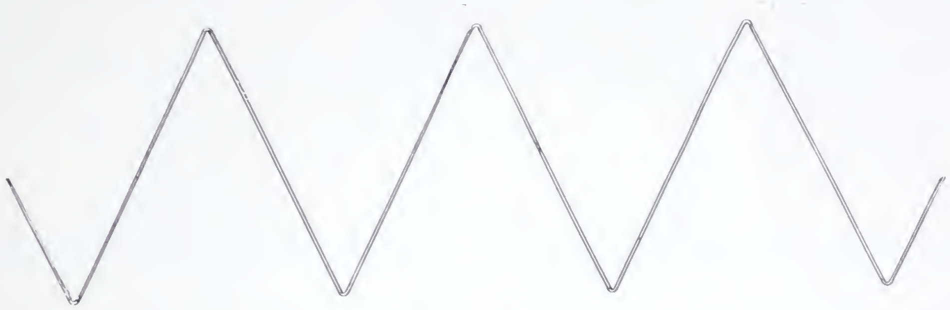
This new method of reinforcement, being essentially economical and practical, gives increased strength, and is simple to make and fix. Further, which is a point of great importance, it has proved in practice that with a concrete so scientifically reinforced, there is no necessity to provide objectionable expansion joints filled with plastic material, which joints sooner or later become useless through being caulked with pebbles, grit, or other débris and thus cease to exercise their function as expansion joints.

THE PYRAMIDAL INTERLOCKED REINFORCEMENT.

Having now perhaps aroused the curiosity and interest of the reader, we hasten to explain what is considered the correct method of reinforcing concrete, and refer him to the following sketches. These sketches and photographs illustrate the method of pyramidal interlocked reinforcement introduced and used extensively on various undertakings for reinforced concrete roads, foundation rafts, platform and retaining walls, floors and walls of grain sheds, silos, reservoirs, etc. It will be observed that the interlocked framework consists of a top and bottom layer of bars connected together by zig-zag inclined bars which latter form pyramids of diagonal tension members. These zig-zag bars radiate in various directions from the point of contact of any superimposed rolling load and provide the necessary resistance to the diagonal tension stresses in a similar manner to the diagonals in the well-known type of Warren Girder. Should any particular part of the road formation be faulty, the function of the reinforced concrete is to spread the load over on to the adjacent areas capable of supporting the weight, hence the necessity for the upper and lower layers of reinforcement with the intervening interlocked diagonal bars.

METHOD OF ASSEMBLING.

It will be noticed that the pyramidal reinforcement consists of bent bars combined with various straight bars. No. 1 bent bar is a bar bent zig-zag, thus :—



BAR 1.

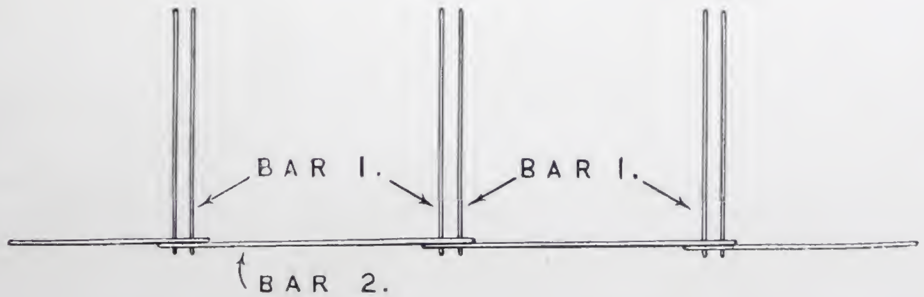
These bars for road reinforcement are usually $\frac{1}{8}$ in. or $\frac{3}{16}$ in. diameter and are quickly bent to shape on a bench studded with iron pegs spaced at the requisite distances. With a little practice, it is remarkable how few seconds are required by the average steelworker provided with two short lengths of tube threaded on the bar to bend to shape a length of 40 ft. of such a bar. The wire is delivered in coils, and after being stretched out at site by means of a winch, is cut to any desired lengths.

No. 2 bent bar is shaped thus, and usually has about six loops :—

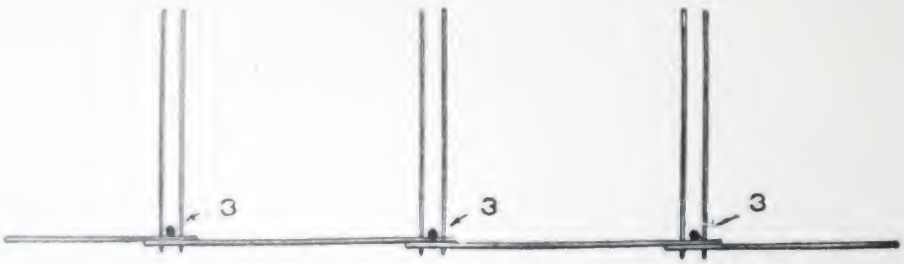
BAR 2.

and is similarly easily and quickly bent to shape over oval pegs set in a board, by means of a simple bent steel tool forked at the ends like a claw used for extracting nails out of timber.

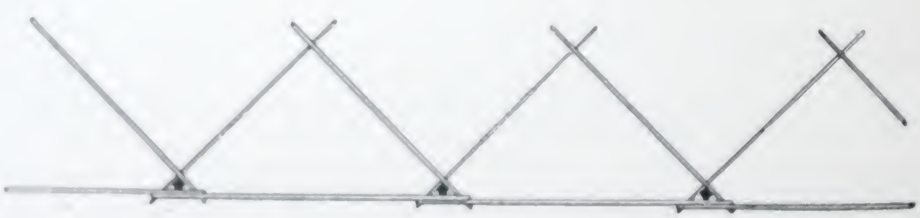
The bars No. 1 are suspended in parallel pairs over a wide bench on three or more removable supports. The loop bars No. 2 are then threaded on to the zig-zag bars, so that a pair of the latter bars pass through each loop, thus :—



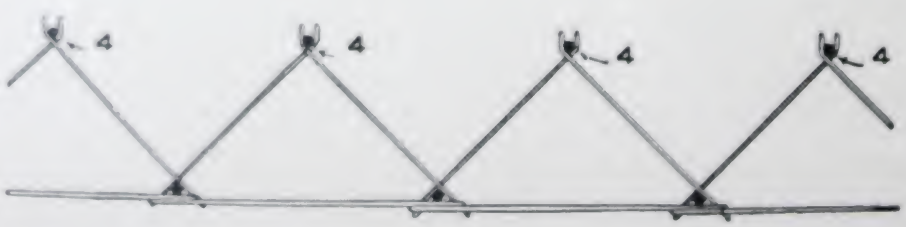
Longitudinal bars " No. 3 " are then placed between each pair of zig-zag bars, and rest on each of the loop bars No. 2 thus :—



The zig-zag bars are then crossed over one another and so lock the horizontal bars firmly, thus :—

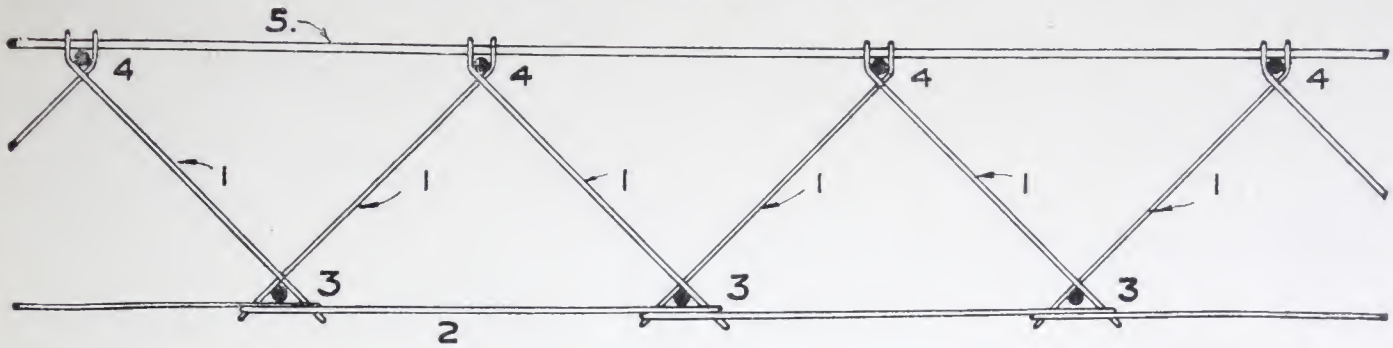


on to the saddles thus formed at the top of the zig-zag bars, further longitudinal bars " No. 4 " are placed to form the upper layer of reinforcement of the birdcage, thus :—



The bars " No. 4 " are again locked into place by means of transverse bars " No. 5 threaded through between the underside of the top bend of the zig-zag bar and the top of the longitudinal bars "No. 4," thus :—

Fig. A **SECTION A.B.**



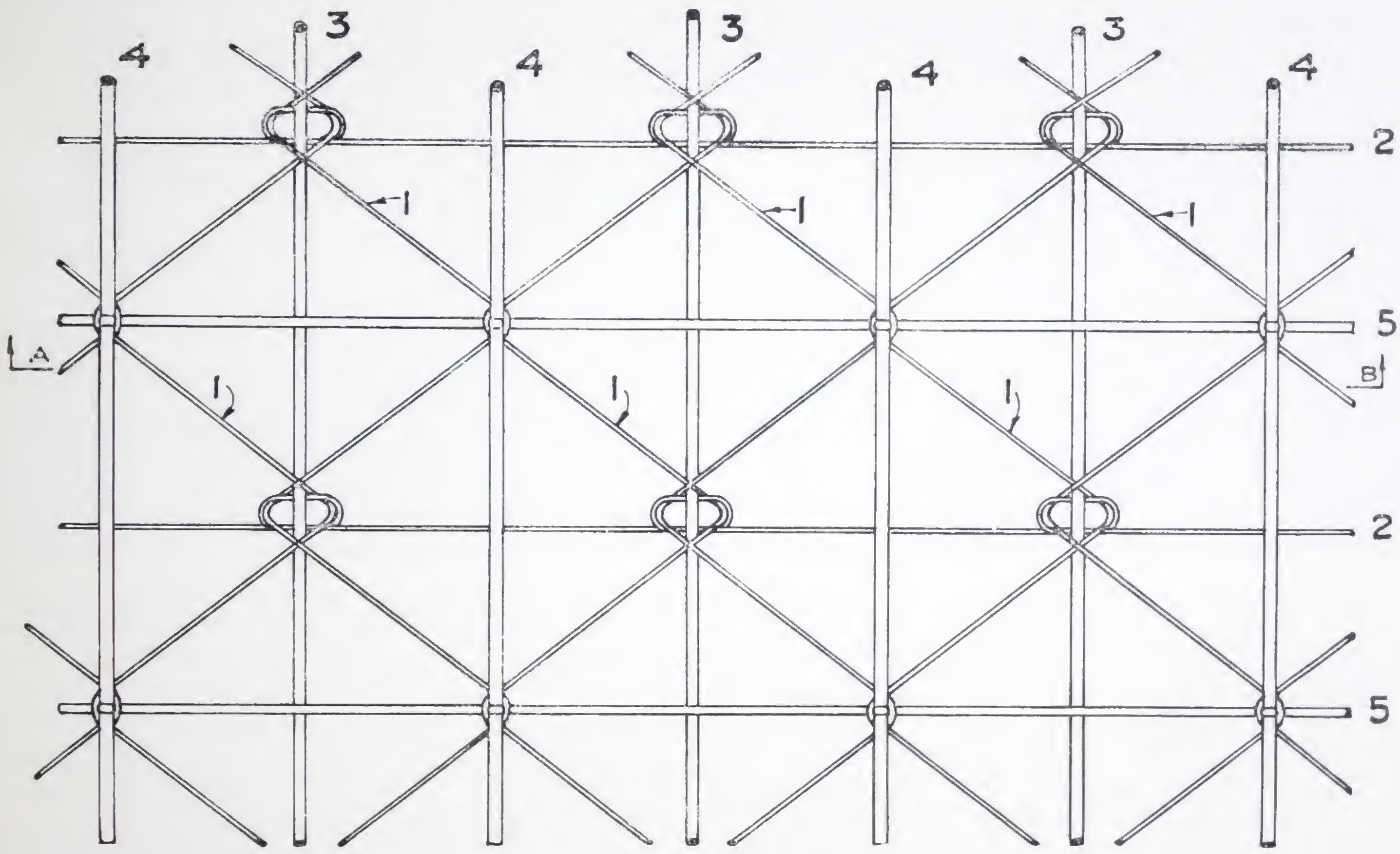


Fig. B **PLAN.**

The reinforcement is then complete and is so interlocked and rigid, that it can be subjected to considerable rough treatment without injury or displacement of the component bars. It is usually made in convenient sizes about 20 ft. to 24 ft. long by 6 ft. to 8 ft. wide. The adjacent lengths are easily and quickly connected to one another in position on the ground.

The framework being complete and in position on the road formation, any additional bars are quickly and easily attached at convenient spacings by means of short lengths of annealed wire and the whole reinforcement is assembled ready for the concrete to be dumped and punned into position without any fear of displacing the bars. The framework to start with, usually rests directly on the formation, and a layer of about 2 in. of concrete is put down through the framework on to the formation. The framework is then lifted so that it rests on the top of this 2 in. layer and then concreting is resumed up to the desired thickness. This method suffices to give the necessary cover of concrete below the underside of the reinforcement. The method of making the pyramidal reinforcement as above described is simplicity in itself, and the labour cost is small.

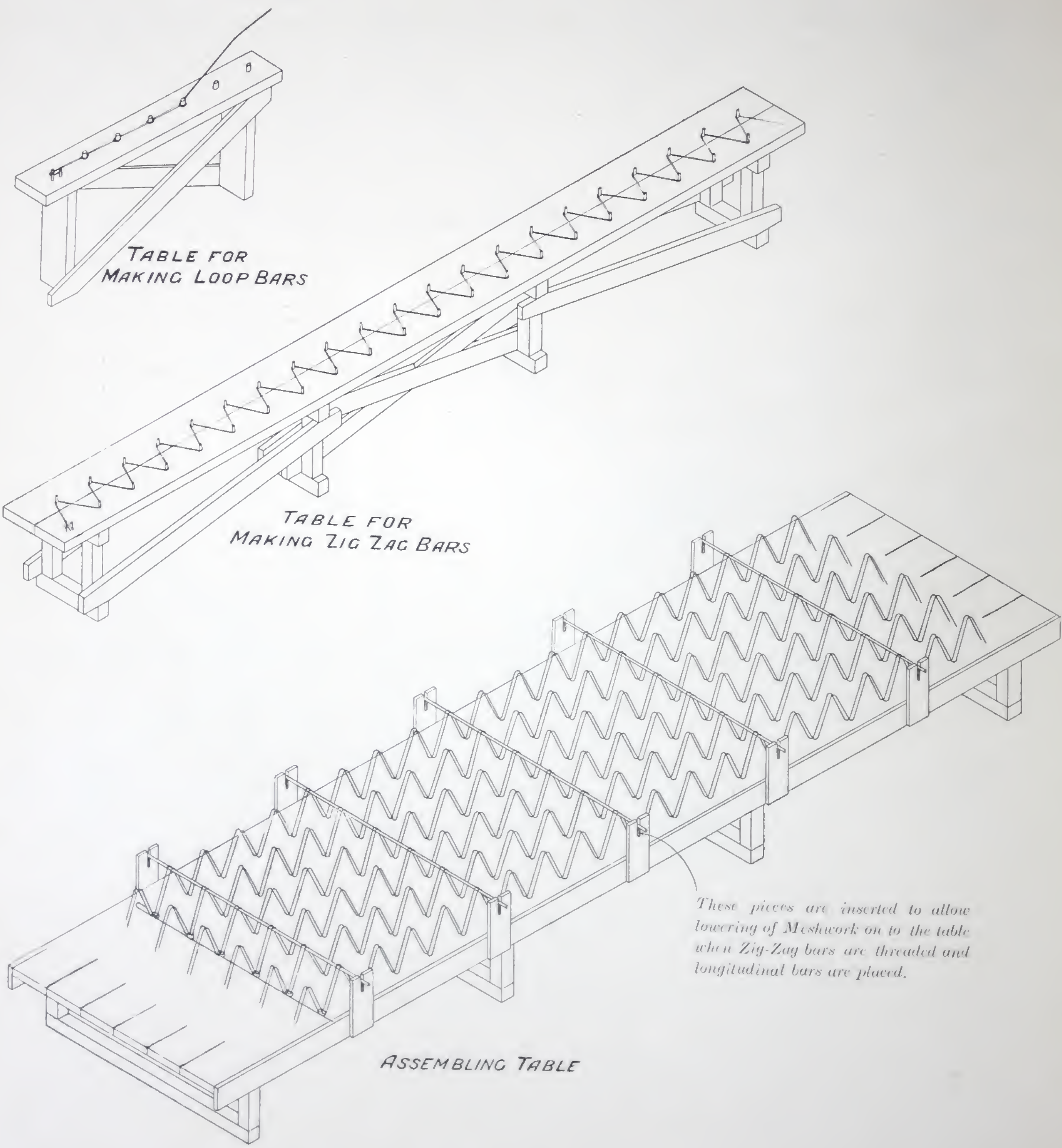


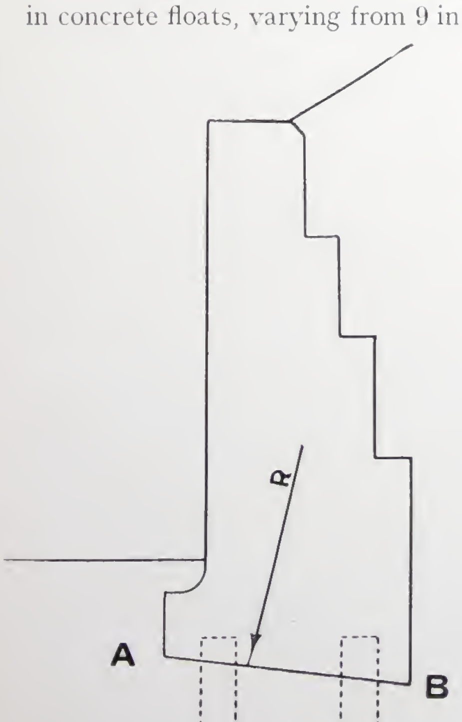
TABLE FOR
MAKING LOOP BARS
TABLE FOR
MAKING ZIG ZAG BARS
These pieces are inserted to allow lowering of Meshwork on to the table when Zig-Zag bars are threaded and longitudinal bars are placed.
ASSEMBLING TABLE

THE COMPLETED REINFORCEMENT

The completed reinforcement when in position appears so scientifically correct, and looks so neat and machine made, that to one uninitiated into the secret of its construction it appears costly and extravagant whereas, as already mentioned, **the reverse is the case** owing to the ease of manufacture on the site with plain bars delivered straight from the steelworks.

The reinforcement can be economically assembled in slab form, either perfectly flat or of thicknesses varying upwards from 1 in. For a 3 in. concrete slab, a suitable thickness of reinforcement is 1 in., while for 18 in. solid or cored construction the framework may have a distance between the upper and lower layers of 15 in. In the former case the bases of the pyramids can be suitably about 15 in. by 12 in., and in the latter according to requirements.

Its use in foundation rafts will be perfectly obvious. It has been most successfully used on bad ground in concrete floats, varying from 9 in. in concrete roads and supports for railway tracks to 18 in. in heavy floors for machinery shops containing lathes, shears, steam-hammers, etc.



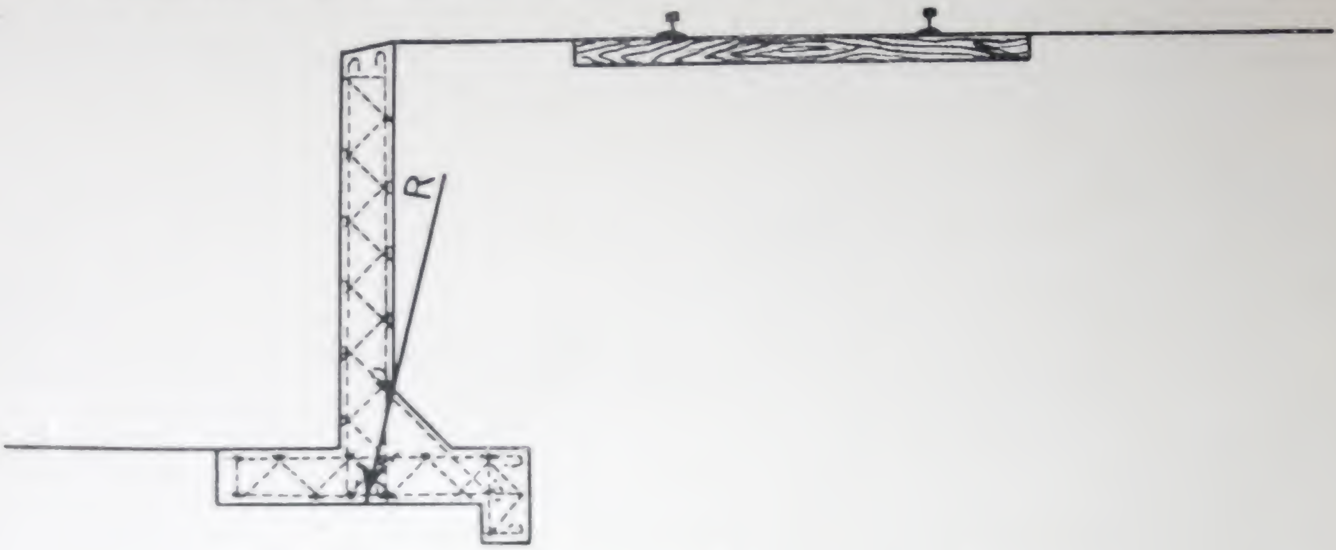
RETAINING WALLS.

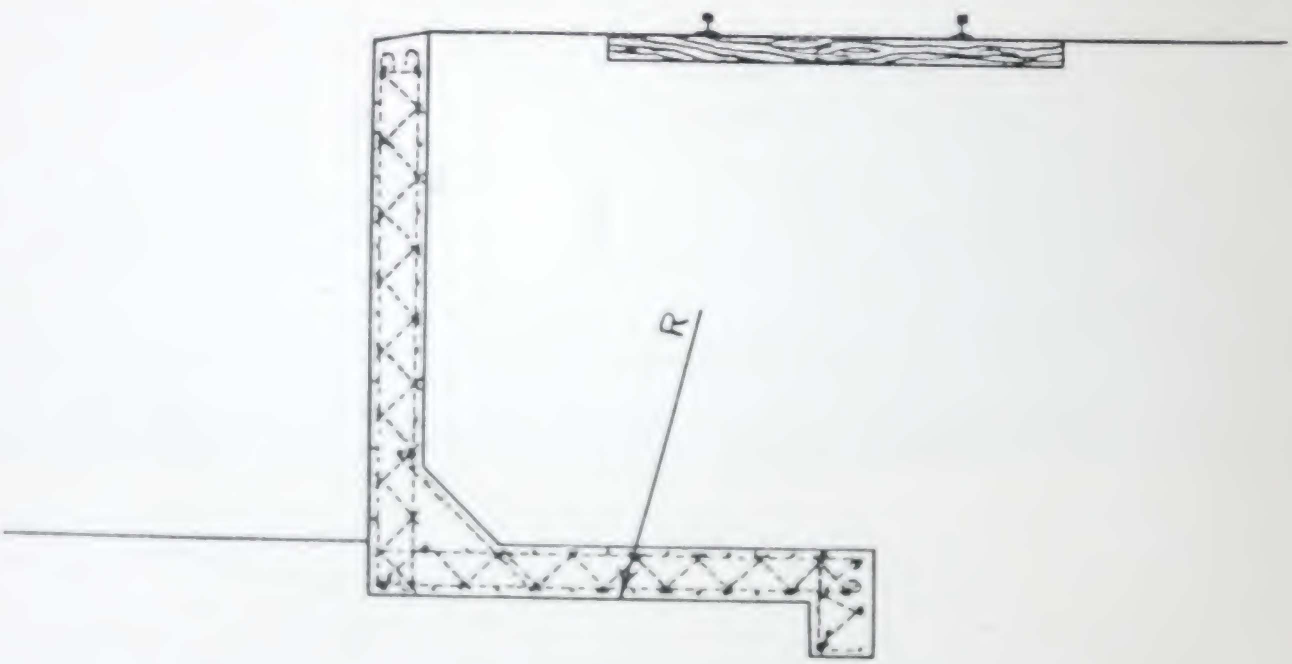
It quickly became apparent that this type of reinforcement was specially adapted to retaining walls on bad ground, where piled foundations were, as a matter of economy, considered undesirable.

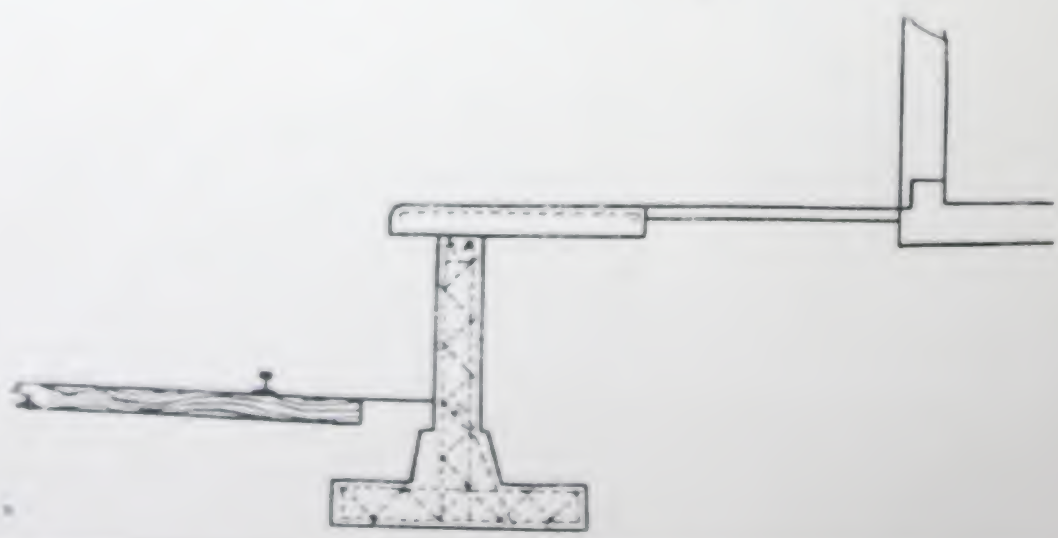
In the ordinary type of gravity wall the resultant line of thrust due to the weight of the wall and the thrust of the earth usually strikes the base of the wall as shown, with the result that the pressure per square foot at underside of the toe "A" is usually twice the average intensity over the whole cross-section. Consequently this pressure often exceeds the safe-bearing capacity of the formation, in which case it is necessary at great expense to pile the whole length of wall both at the toe "A" and heel "B."

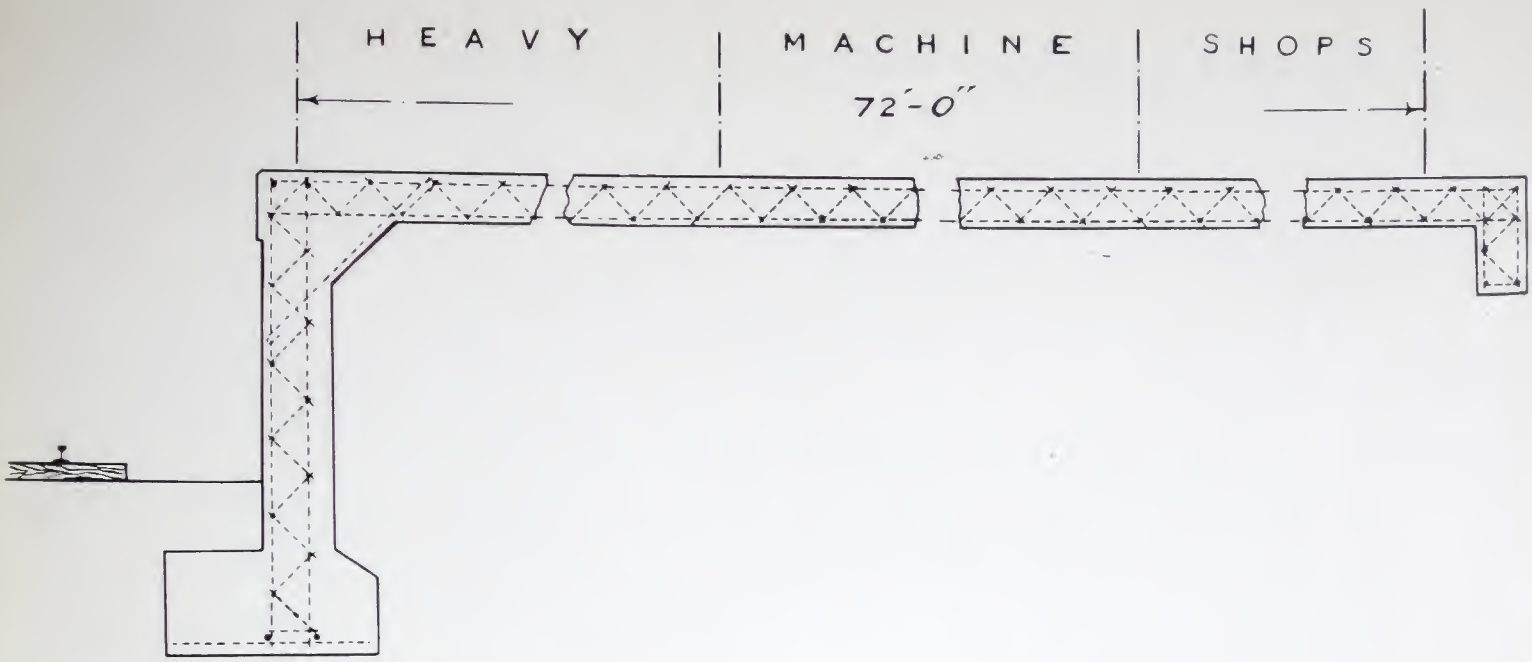
With the use of the pyramidal reinforcement with its consequent cheapness of raft and wall construction, it is possible to so design a retaining wall that the line of thrust above-mentioned shall strike the base of the wall in the centre of its width, and thus give equal bearing pressures over the whole cross-section. This results in the maximum bearing-pressure being, in this case, half that in the case of the gravity wall, thus permitting the safe omission of piles.

A few examples of the extensive use of the reinforcement in retaining walls are here illustrated:—

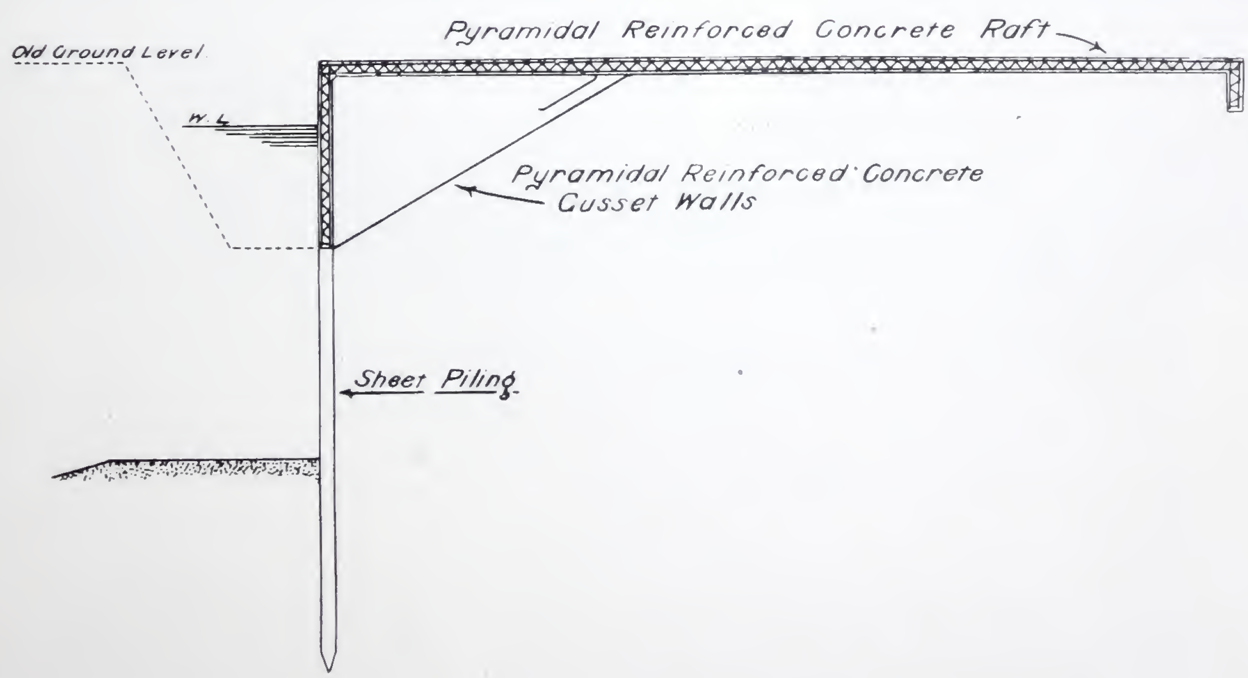








The reinforcement has been found very useful in conjunction with reinforced concrete sheet piling, where the thickness of the 14 in. piles would otherwise have been insufficient to withstand the 30 ft. head of earth pressure at low water, thus :—



It will be obvious from a study of the above cross-sections that the success of the above type of retaining wall is dependent upon the successful solution of an economical type of concrete raft capable of spreading a load over a sufficiently large area of ground of indifferent bearing capacity. Hundreds of yards of platform walls surrounding piled transit sheds have already been built on this system and many more are in course of construction.

ECONOMIC BUILDING OF WALLS.

As before stated, the interlocked reinforcement when made is rigid, and can be handled easily. If necessary it can be placed vertically and gives a stiff and firm reinforcement capable of supporting itself. This is a particularly useful qualification in the economical building of walls. In the usual method of reinforced concrete wall construction, the reinforcing bars are placed singly in position and tied up or otherwise connected in a more or less slipshod method in the wood framework, with a tendency to use bars of greater section than theoretically desirable on account of their stiffness and rigidity to enable them to stand up by themselves. The method now adopted, however, is the reverse of this. Instead of the wood framework supporting the steelwork, the steelwork supports itself, and may, in addition, support the woodwork. No loose bars are to be seen swinging in the wind, and the whole assemblement of steel reinforcement both looks and is a ship-shape, economical and satisfactory arrangement, whereby the timber framework need only be brought up in short lifts as required. Further, the bars can be of as small section as desired as they are easily attached by annealed wire to the rigid framework. It is an interesting fact that walls have been built on this principle without the use of any framework either of wood or steel. In this case the faces of the wall were either unexposed or afterwards plastered. The concrete was retained in position by means of canvas fastened temporarily to the outside of the framework.

PLATFORM-WALL AND RAFT AT ROYAL ALBERT DOCK.

PLATFORM-WALL AT VICTORIA DOCK.

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PLATFORM-WALL AND RAFT AT ROYAL ALBERT DOCK.

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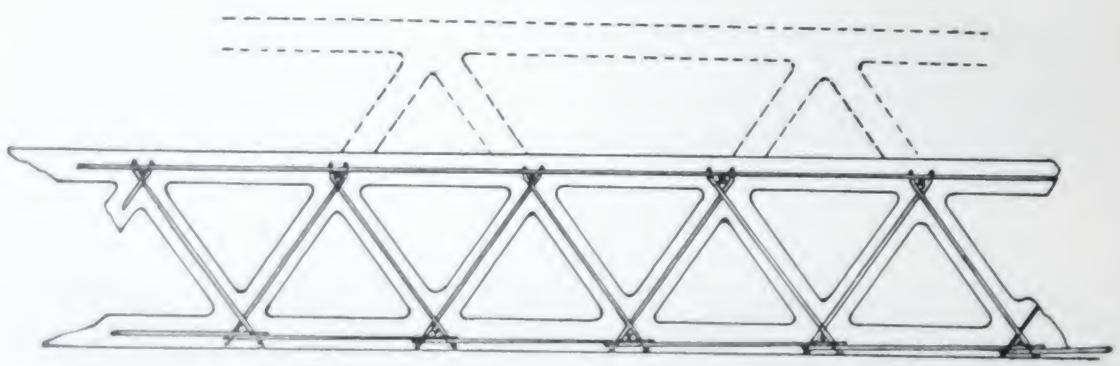
HOLLOW WALLS.

When one had once constructed a solid vertical wall on this principle, the next step was a perfectly natural and obvious one. One of the objections to a solid concrete wall for buildings is that it is a " cold " wall, and with a sudden drop in temperature, the internal faces stream with moisture. A case in point is that of a comparatively old flour mill built of solid walls 12 ins. thick in reinforced concrete. In spite of a hot air system, recently and specially installed, no sooner does a drop in the outside temperature occur than the insides of the outer walls of the building are streaming with internal condensation moisture, similar to the panes of glass in the window frames of a dwelling house. A system of hollow wall construction for the outer walls of buildings is the obvious and efficient remedy. This has been in vogue for a long time, and is the subject of many a patent specification.

To obtain this result, combined however with maximum strength and economy, and so to make the wall a monolithic reinforced slab throughout its length, breadth and thickness, has been the subject of a great amount of thought and experiment. With the interlocked reinforcement, this is a natural development, and is now in use on the construction of a large reinforced concrete shed for the storage of loose and sacked grain.

A section through a hollow wall of this type is shown on the drawing below. It will be seen that the wall consists of one complete reinforced slab equally strong in all directions. In one direction its strength is that of a lattice girder, whilst in other direction, at right angles, its strength is that of a corrugated slab strengthened by top and bottom flanges of reinforced concrete.

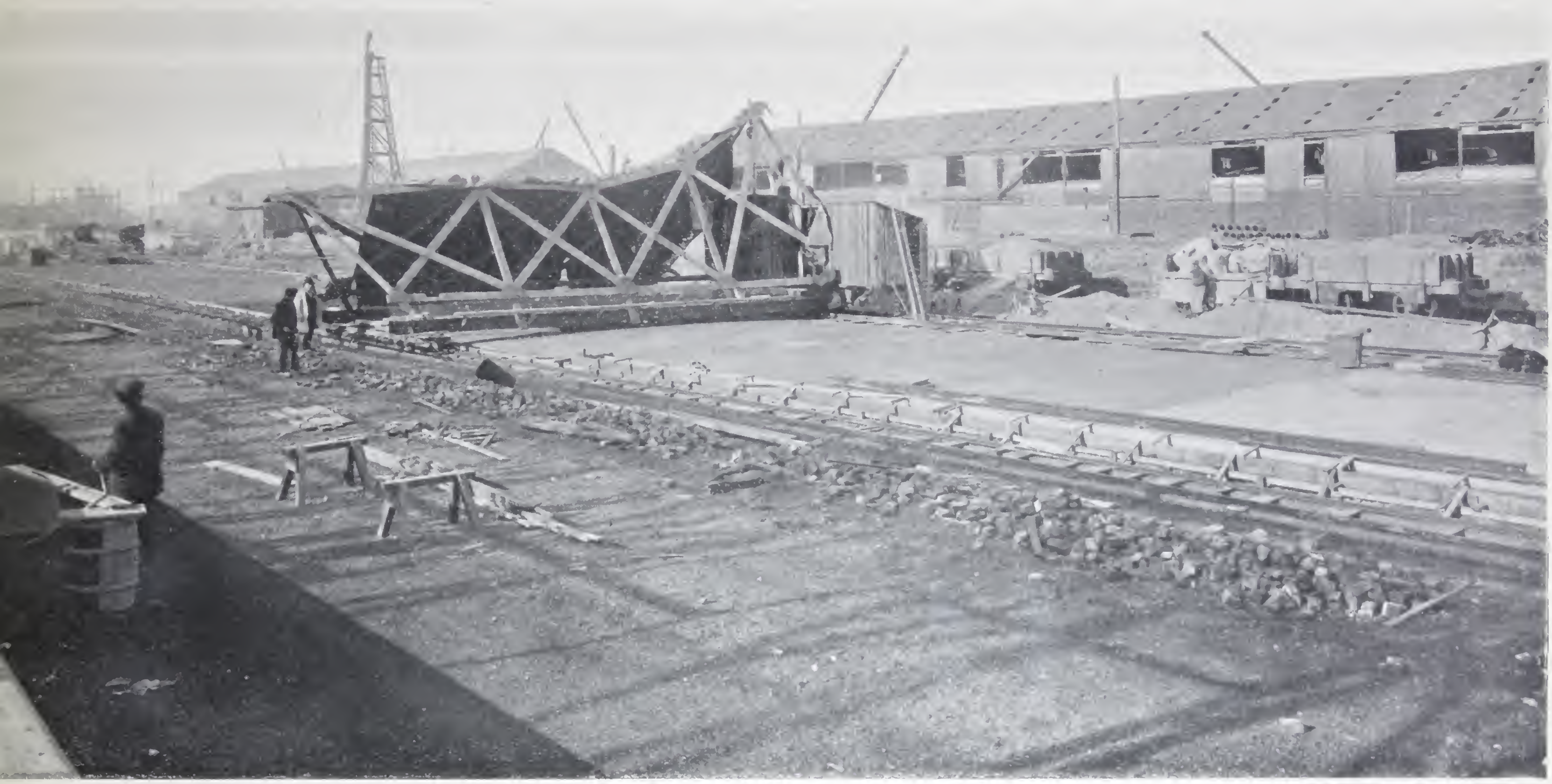
The weight of a hollow wall is considerably less than that of a solid wall, which is a matter of very great importance. Any increase in width of the hollow wall within reasonable limits, as shown by dotted lines, results



in a wall not only of the same weight per square foot of area, but also in a wall of much greater strength, due to the fact that the steel reinforcement in the flange slabs has an increased radius of gyration. The triangular hollow spaces are easily and conveniently made. The wall is built up in layers and the concrete carefully punned in among the reinforcement. The cores consist of collapsible and cheap triangular boxes of a novel and effective design. Such boxes are raised up as the concrete partly sets. The applicability of this method of construction to ship or barge-building is obvious. The steelwork is built up as a rigid framework shaped to all desired curves, the timber forms are erected and attached to the steelwork and the concrete put into place. Such construction ensures a dry hold free from internal condensation. Should the outside skin be accidentally broken by collision or otherwise little inconvenience is occasioned. A little extra pumping is required until repairs can be effected on the hard or in the dry dock. Each vertical core hole is connected at the base with the bilge by means of a small outlet which limits the amount of water that can pour into the bilge from any damaged cell. A little thought and consideration will make clear the superiority of this method over that of rib and panels. In the latter system, any extensive damage to the side of the ship or barge involves a flooded hold and perhaps total loss of the vessel. Further, in the rib and panel systems timber linings have to be provided at considerable extra expense to keep the damageable cargo from touching the concrete sides.

The application of hollow walls, easily erected, is unlimited. Not only are they useful for warehouses and dwelling houses, and cold storages, etc., where non-conductants of heat and freedom from percolation and internal condensation are the chief factors, but being cheap and using less material than solid walls they are exceedingly useful for light boundary walls, etc., on bad ground.

The wide application of this system of reinforcement has resulted in extensive investigations with regards to the facilities for reducing hand labour in the placing of the concrete in position in the structure.



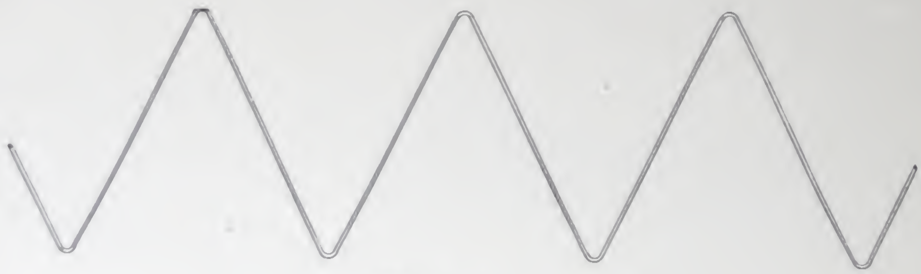
Concrete is a very heavy material weighing about 130 lbs. per cubic foot, and it is readily seen that in these days of high wages, the employment of hand labour to handle concrete in small quantities is to be avoided when it is possible to employ very light and cheap crane structures such as have recently been designed to handle concrete either in the wet condition or in pre-moulded members. It is not intended to describe these various machines at length here. One of them is a road-making machine handling 1-ton loads of concrete in the making of a 33 ft. roadway. This lays and floats off the concrete as it proceeds at a cost of less than half that of hand labour. It was put into use on the roadway, as illustrated above, and has proved highly satisfactory. Being entirely covered in with awnings the work can be proceeded with irrespective of weather conditions. Another traversing machine is a very cheap and efficient crane structure for use in building a warehouse 120 ft. wide by 46 ft. high. The machine has a span of 140 ft. and handles loads of 3 tons. It will suffice here to say that the main principle of the machines consists of traversing the load on a carrier running on a wire rope suspended from the underside of an over-head strut, which latter is itself in turn suspended from suitable movable supports. Cranes of this type range in lifting capacity of between 3 cwts. to 30 tons, and have spans from 16 ft. to 150 ft., and may be used for a variety of purposes from a park wall to the building of an 18,000 ton liner.

The machines above described are built on entirely novel and new principles, and possess the **combined qualities of cheapness, lightness and quick-working.** A complete description, with diagrams, of two of these machines was given in the issue of "Concrete and Constructional Engineering" for the month of January, 1919.

Before leaving this point of our subject, which, to an erecting or mechanical engineer is full of interesting problems it is desirable to lay stress upon the fact that too much care and trouble cannot be spent upon thinking out the method of procedure and the selection of plant necessary to expedite the placing of the concrete in position in as economical and efficient a manner as possible. In view of the recent experiments proving the detrimental effects of using concrete in such a wet state as to permit of its running down shoots, it is desirable to utilise methods by means of which the concrete can be mixed to the proper consistency and placed in position so as to obtain the greatest ultimate strength. This important consideration was always kept well in mind in the design of the crane apparatus above-mentioned.

It will perhaps have been noticed that up to now these notes on reinforced concrete have been confined to slab work such as road beds, rafts, walls, etc. It is to be understood that all the previous remarks in reference to the desirability of an easily made, rigid, skeleton framework reinforcement, apply equally to **girders, columns, telegraph poles, piles,** etc., as to slab work. The method of reinforcement is, to all practical purposes, identical. The procedure is as follows :—

Two lengths (1) of say $\frac{3}{16}$ in. diameter bars are bent over pegs fixed in a bench, to the following shape :—



BAR 1.

Two lengths more (2) of similar section bars are bent over another set of pins to the same longitudinal pitch but of less height, thus :—

BAR 2.

Looped pieces (3) to rest in the valleys of the zig-zag are bent over suitable pegs, thus :—

3.

One bar each of (1) and (2) are arranged in pairs and suspended upon suitable removable iron bars, and the loops (3) are threaded over them so that each rests in a valley of the two pairs of bars (1) and (2), thus :—

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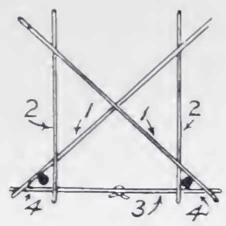
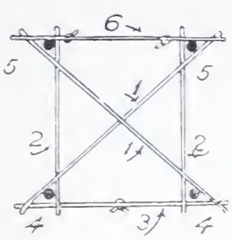
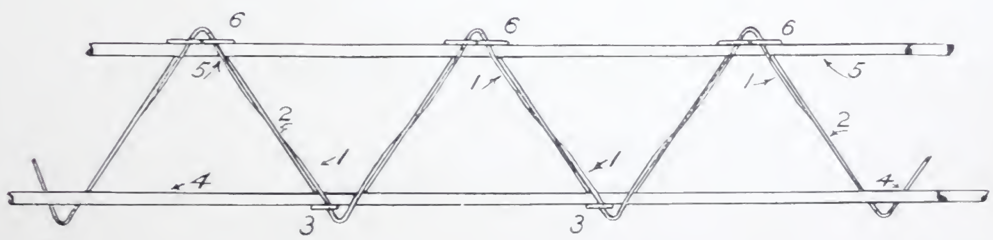
A horizontal bar (4) is then placed between each pair of zig-zag bars so as to rest on the looped bars (3) and then the zig-zag bars (1) are pulled over towards and across one another so as to lock the horizontal bars (4) in the framework, thus :—



Two longitudinal bars (5) are then placed in position to rest on the saddles formed by crossing the bars (1) and (2) and the whole is locked to form a rigid reinforcement, which can be handled by a crane, by inserting bars 6 between the top of the zig-zag bars and the top of the longitudinal bars (5) thus :—



The appearance of the resulting reinforcement in elevation or plan is thus :—



It will be recognised that the interlocking is exactly similar to the slab reinforcement with the slight difference that in cross-section the triangles are right-angled instead of being isosceles triangles.

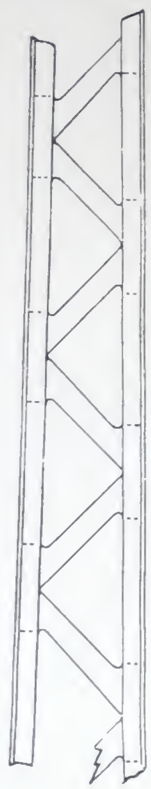
It is desirable to make the framework as conveniently light as possible for handling, providing there is sufficient section in the bars to give rigidity. Any additional reinforcement either for tension or diagonal tension stresses is attached as required.

If it is necessary or thought desirable to make a concrete member such as a telegraph pole, or a pile tapering from end to end this is easily and readily accomplished by varying the setting of the pegs in the benches.

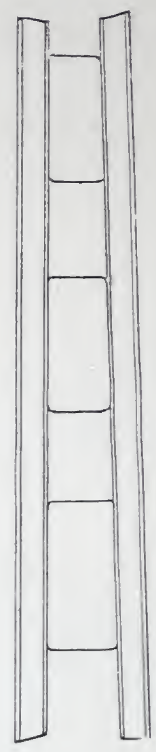
Again, in a similar manner to the hollow wall, the telegraph pole or column may be cored for the sake of lightness, appearance, or other purposes, for instance, in the case of a telegraph pole, to provide footholds, making the pole easy to climb.

The appearance of the pole is thus :—

FRONT VIEW.



BACK VIEW.



Although the discovery of this method of reinforcement dates only from the latter part of 1917, very extensive works have been carried out, and others are in progress, under this system including reinforced concrete roads, sheds, retaining walls, platform walls, reservoirs, column bases, etc. The Port of London Authority use this system extensively in connection with their schemes of improvement.

The method of reinforcement above described forms the subject of a Patent No. 117,915, June 8th, 1917, taken out by Mr. J. H. Walker, Assoc.M.Inst.C.E.

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